Extrinsic Temporal Metrics*

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1 Introduction

When distinguishing absolute, true, and mathematical time from relative, apparent, and common time, Newton wrote: "absolute, true, and mathematical time, in and of itself and of its own nature, without reference to anything external, flows uniformly" [Newton 2004b: 64]. Newton thought that the temporal metric is intrinsic. Many philosophers have argued—for empiricist reasons or otherwise—that Newton was wrong about the nature of time. They think that the flow of time *does* involve "reference to something external." They think that the temporal metric is extrinsic. Among others, Mach, Poincaré, and Grünbaum seem to accept this view.[1] And these are not the only two views available. Perhaps both Newton and his opponents are wrong and there is no temporal metric at all.

Who is right? On the standard ways of understanding general relativity, quantum mechanics, special relativity, and Newtonian mechanics, these theories all postulate an intrinsic temporal (or spatiotemporal) metric. So, although we cannot know what future theories will look like, the evidence favors an intrinsic tempo-

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[1] [Mach 1960: 272-3], [Poincaré 2001], [Grünbaum 1968]. The claim that some other bit of geometrical structure is extrinsic also shows up in many places. Reichenbach [1957: 14-37] seems to believe that the spatial metric is extrinsic, defined in terms of the behavior of rigid rods, though his writing is difficult to interpret. And some interpreters attribute to Mach the claim that the affine structure of spacetime is extrinsic, defined in terms of the large-scale behavior of matter (see, for example, Friedman [1983: 67]).

ral metric. There are dissenters, though; Julian Barbour does not think there is an intrinsic temporal metric, and has developed alternative physical theories that do without one.[2]

I will not say anything here to settle this debate. Instead, my goal in this paper is a conceptual one. I want to clarify the relationship between the claim that the temporal metric is extrinsic and conventionalism about time. According to conventionalism, some appeal to our conventions must be made to explain how there could be an extrinsic temporal metric. I will argue that conventionalism is false. Extrinsic temporal metrics are as non-conventional and objective as the intrinsic temporal metric that Newton believed in. Section 5 contains my argument, and a presentation of some alternatives to conventionalism. Sections 6 and 7 consider objections to my view.

Sections 2 to 4 are devoted to preliminaries: I say more about the difference between intrinsic and extrinsic metrics, and propose a definition of "conventionalism about the temporal metric."

2 Intrinsic Metrics, Extrinsic Metrics

We can represent a temporal metric, mathematically, in many ways: as a function from pairs of times to real numbers, for example (where the number gives how many seconds elapse between those two times); or as a function from points of spacetime to functions from tangent vectors to real numbers (that is, as a one-form). In this paper I take a temporal metric to be a relation like *x and y have the same temporal length*, or *the same amount of time passes during x as during y*—a two-place congruence relation on time intervals that (together with the betweenness relation on instants of time) satisfies some standard set of geometrical axioms, such as Hilbert's axioms for neutral geometry. (I assume that the other mathematical representations can be recovered from the facts about how this relation is instantiated using a representation theorem. I also assume that we do not live in a relativistic world and that substantivalism is true, so that there are such things as times and time intervals to instantiate these relations. But I make these assumptions only to

[2] [Barbour 1999] contains an elementary summary of Barbour's theory.

simplify the discussion. I believe that much of what I say remains true even if they are dropped. Of course, in the context of relativity theory, I would be discussing extrinsic *spatio*temporal metrics.)

What, then, does it mean to say that the temporal metric is intrinsic, or that it is extrinsic? There are standard intuitive explanations of what it is for a property or relation to be intrinsic, or extrinsic. An intrinsic property is one that characterizes something that has it as it is in itself. What intrinsic properties something has does not depend on what else there is, what those other things are like, or how it is related to them. Similarly, an intrinsic *relation* is one that characterizes some things as they are in *them*selves. (For example, it is plausible that the relation *x has the same mass as y* is intrinsic: the existence of things other than *a* and *b* (and their parts) plays no role in determining whether *a* and *b* are equally massive.[3]) Extrinsic properties and relations are those that are not intrinsic.

This explanation is not entirely clear: what does "in itself" mean, and what sort of dependence is at work? Many philosophers have attempted to give more precise definitions of "intrinsic."[4] For this paper I will not need the precision that these definitions provide, so I will be content to use the intuitive explanation.

Figuring out whether a temporal metric is intrinsic or extrinsic is just a matter of applying this general characterization to the relevant temporal congruence relation. Indeed, we then end up back at the characterization Newton uses: extrinsic metrics do, and intrinsic metrics do not, involve "reference to something external"—something other than times.

Let's look at an example. Suppose that for two temporal intervals to have the same length is for the earth to rotate through the same number of degrees during each of them. Then the temporal metric is extrinsic. Congruence of temporal intervals is analyzed in terms of the concrete physical processes that occur during those

[3]This relation is also usually thought to be internal: it supervenes on the intrinsic properties of its relata. But it is not necessary that intrinsic relations are internal.

[4]See, for example, papers by Weatherson, Lewis, and others in the September, 2001 issue of *Philosophy and Phenomenological Research*. Horwich [1975] and Glymour [1972] discuss how to define "intrinsic" in the context of the debate about whether the metric is intrinsic.

intervals—in this case, the rotation of the earth.[5]

In my example the temporal metric is analyzed in terms of the rotation of the earth. But of course it may be that the temporal metric is extrinsic but congruence of temporal intervals is analyzed in terms of some other physical process. It might, for example, be analyzed in terms of the period of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom. Or it might have some more complicated analysis. But I will continue to use the earth's rotation as my canonical example.

Is any relation that has an analysis relevantly similar to the two examples given so far a candidate extrinsic temporal metric? What about the relation *my watch ticks the same number of times during x as during y*? Call this relation "*R*." If the temporal metric is extrinsic, could it turn out that *R* is the temporal metric?

It depends on how my watch behaves, but the likely answer is "no." Suppose, as is likely, that my watch stops ticking some time in the next fifty years. I assume that there is not a last moment of time, so there are infinitely many times after the last tick of my watch. So every time interval located after the last tick of my watch bears *R* to every other such interval. But then *R* does not behave the way a congruence relation must behave. For example, it follows from the axioms of neutral geometry that each interval has a unique midpoint. But if t_1 and t_3 are times after my watch stops ticking, there is no *unique* time t_2 between them such that the interval from t_1 to t_2 bears *R* to the interval from t_2 to t_3.

(These considerations probably also bar *the earth rotates through the same number of degrees during x as during y* from being the temporal metric. But I don't think they bar every extrinsic relation on temporal intervals from being the temporal metric. To keep things simple, I will stick with *the earth rotates through the same number of degrees during x as during y* as my main example.)

[5]One interesting feature of this analysis is that it presupposes that there is a spatial metric. The analysis makes sense only if there are facts about whether the earth has rotated through the same distance during two intervals. (For all that has been said, though, the analysis does not presuppose that the spatial metric is *intrinsic*.) Is it possible to give an extrinsic analysis of the temporal metric (or the spatial metric, for that matter) without presupposing that there is any other metric around? I do not know.

Now that we've seen what an extrinsic temporal metric might look like, I want to make two points about such metrics. First, to say that the temporal metric is extrinsic is not merely to say that the time between two events depends, as a matter of physical law, on what physical processes happen between those two events. Something like this is true in general relativity; but in general relativity (standardly interpreted) the (space)time metric is not extrinsic. Second, to say that the temporal metric is extrinsic is not to say that the earth turns out to be a perfect instrument for measuring independent facts about the lengths of temporal intervals. If the temporal metric is extrinsic, then the earth's rotation does not measure the time; it sets the time.

So much for extrinsic temporal metrics. What about intrinsic temporal metrics? Unlike extrinsic metrics, intrinsic temporal metrics cannot be analyzed in terms of periodic physical processes. But it is hard to give a positive characterization of them. Most who believe that the temporal metric is intrinsic also deny that anything informative can be said about what makes two temporal intervals the same length: this is just a fundamental fact about those time intervals.

Under certain assumptions about the topology of time, there may be something informative to be said about an intrinsic temporal metric. Suppose that time has the order-type of the integers—each instant of time has an immediate successor and an immediate predecessor. Then one might say that what makes two temporal intervals the same length is that they contain the same number of instants. A temporal metric defined in this way using the temporal topology would be intrinsic. But in our world time is densely ordered; there are infinitely many instants between any two. So if there is an intrinsic temporal metric in our world, it cannot be analyzed in this way.[6]

Let me make two more points about intrinsic temporal metrics, to make sure we have grasped the concept. First, even if the temporal metric is intrinsic it is possible that the earth's rotation is a perfect instrument for measuring time. That is, it is possible that two temporal intervals have the same length just in case the earth ro-

[6] Grünbaum [1968: 12-3] seems to believe that if there is an intrinsic temporal metric, then it has an analysis in topological terms. Sklar [1974: 109-12] and Friedman [1983: 301-9] dispute Grünbaum's claim.

tates through the same number of degrees during each of them. But in this situation it is not the earth's rotation that *makes it the case* that the two temporal intervals have the same length. Second, that we refer to particular physical processes when we define the unit we use to measure time does not entail that the temporal metric is not intrinsic. In fact if we define our unit by saying something like, "temporal interval x is one day long iff as much time passes during x as during the temporal interval occupied by the last complete rotation of the earth," then we *presuppose* that there are already facts about which temporal intervals have the same length.

Typically, people who disagree about whether the temporal metric is intrinsic or extrinsic also disagree about some associated modal claims. Those who believe that the metric is intrinsic typically believe that time could pass in an otherwise empty universe; those who think that the metric is extrinsic typically believe that there can be no time without change. It is easy to see why these modal claims are typically associated with the corresponding view about the nature of the temporal metric. If metaphysical possibility is governed by some kind of combinatorial principle, then that the metric is intrinsic *entails* that time could pass in an otherwise empty universe. And the standard examples of extrinsic metrics have it that the amount of time that passes between two instants is defined in terms of the physical processes that occur between those two instants. For metrics like that there can be no time without change. (The definition of "extrinsic metric" leaves it open, though, that the amount of time that passes between those two instants is defined in terms of events and processes that do not occur between them.)[7]

There is another important modal difference typically associated with the difference between intrinsic metrics and (some) extrinsic metrics. If the metric is intrinsic, then every physical process could have happened faster than it actually happens. Indeed, if the metric is intrinsic, then the entire universe could have evolved in time faster than it actually does: it could have passed through the same sequence of instantaneous states that it actually does, but at a faster rate.[8] (If it did so, some

[7]Thanks to Frank Arntzenius for pointing this out.

[8]Cross-world comparisons of speed are tricky, especially if you think that the fundamental facts about temporal distance are facts about which temporal intervals are congruent to which other temporal intervals. But there is a similar modal dif-

laws of physics would be violated; this possibility is not a physical possibility.) But if the metric is defined in terms of the earth's rotation then this is not possible. Since, in that case, how fast some physical process happens involves reference to another physical process (say, the earth's rotation), it couldn't happen that *all* processes happen faster than they actually do.[9]

Proponents and opponents of intrinsic metrics sometimes exploit this modal difference to argue for their view. In the scholium, Newton argues: any process could have happened faster than it actually does; so the temporal metric is intrinsic. Some of Newton's opponents argue: it is not possible that every process could have happened faster than it actually does; so there is no intrinsic metric (See, for example, [Barbour and Bertotti 1982: 296]).

Of course, if the temporal metric is extrinsic, *some* processes could happen

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ference between intrinsic and extrinsic temporal metrics that can be stated without making cross-world comparisons of speed. If the temporal metric is intrinsic, then there is a possible world *w* in which the universe passes through all the same instantaneous states that it actually passes through; but while in the actual world it takes the same amount of time to go from (say) state S_1 to state S_2 as it takes to go from state S_3 to state S_4, in *w* it takes longer to go from S_1 to S_2 than it takes to go from S_3 to S_4.

[9]Three comments. First, I have said that if an extrinsic relation like *the earth rotates through the same number of degrees during x as during y* is the temporal metric, then it is impossible for the entire universe to evolve in time faster than it actually does. But this may not be true of *all* possible extrinsic temporal metrics. In footnote 16 below I give an example of an extrinsic metric for which it may be false.

Second, as I said earlier, whether one recognizes these modal differences depends on one's background modal assumptions. If you have strange enough views about modality, then you won't see a modal difference between intrinsic and extrinsic metrics. For example, if you think that all truths are necessary (an insane but consistent view), then you will think that even if the metric is intrinsic, it is impossible that every process happen faster than it actually does.

Third, I want to make a note on the strength of the modality at work in this paragraph. Since a relation's analysis is essential to it, "could have" and "possible" here express metaphysical possibility. So if the temporal metric is extrinsic, it could not have been intrinsic; those who disagree about whether the temporal metric is intrinsic or extrinsic disagree about a necessary truth.

faster than they actually do. It could have happened that the earth rotated fewer times while Jupiter completed one orbit than it actually does. In a possible world where it does (and the temporal metric is defined in terms of the earths's rotation), Jupiter is orbiting faster than it actually does. But the *earth* couldn't have rotated on its axis faster than it actually does.[10]

3 A Puzzle About Extrinsic Metrics

I said that there is a third possible view: that there is no temporal metric. (Even if there is no temporal metric there is still, I assume, a temporal topology.) It looks easy to say what the temporal facts are, according to this view. If there is no temporal metric, then while the question, "are those two particles getting closer together?" has an answer, the question, "*how fast* are they getting closer together?" does not. That's very different from what we say if there is a temporal metric, either intrinsic or extrinsic; if there is either kind of temporal metric, then the second question does have an answer. In more abstract terms, we can put the difference like this: to say that there is a temporal metric (intrinsic or extrinsic) is to say that time has a geometrical structure. To say that there is no temporal metric, on the other hand, is to say that time lacks a geometrical structure. And there is certainly a difference between having and lacking a certain kind of structure.

But there is a puzzle here. From another point of view, it is difficult to say just what distinguishes the claim that there is a temporal metric from the claim that there is not. The problem is distinguishing between the claim that there is an extrinsic temporal metric and the claim that there is no temporal metric at all. Suppose that the temporal metric is extrinsic, and that it has the canonical analysis I have been using: for two temporal intervals to be the same length is for the earth to rotate through the same number of degrees during each of them. An opponent denies that there is a temporal metric at all. But he still accepts that there is such a relation as

[10]Let T be the interval occupied by the most recent complete rotation of the earth. It is possible that that rotation of the earth occupy time interval T' instead, where T' is a proper part of T. But this does not entail that the earth could have rotated faster than it actually does. Instead, (given that the temporal metric is extrinsic,) T would have been a longer temporal interval than it actually is.

the earth rotates through the same number of degrees during interval x as during interval y. Since he denies that there is a temporal metric, he denies that *this* relation is the temporal metric. It is not identical to the relation *temporal interval x is the same length as temporal interval y.* But what does this disagreement amount to? What does he think this relation is failing to do that the believer in an extrinsic temporal metric thinks it is succeeding in doing? What does an extrinsic relation on times have to do in order to be *the* relation that is responsible for time's geometrical structure?

We can also put the puzzle as a challenge to those who believe that the temporal metric is extrinsic. Suppose that, as before, the temporal metric is extrinsic, and that for two temporal intervals to be the same length is for the earth to rotate through the same number of degrees during each of them. I have been speaking as if, in this circumstance, there is a unique extrinsic temporal metric. But why aren't there lots of them? The relation *Venus rotates through the same number of degrees during interval x as during interval y* appears to be as good a candidate as *the earth rotates through the same number of degrees during interval x as during interval y* for the job of temporal metric. Both are extrinsic relations on temporal intervals that satisfy the relevant set of geometrical axioms. What is the latter relation doing, then, that the former is not, that explains why it gets the job?

One might think that these questions have a false presupposition: that the idea of an extrinsic temporal metric makes sense to begin with. Perhaps it is part of the concept of geometrical structure that something's geometrical structure is intrinsic. If so, then there are really only two positions in logical space—either there is a temporal metric (in which case it is intrinsic), or there is not a temporal metric. To the extent that we are puzzled about the difference between the claim that the temporal metric is extrinsic and the claim that there is no temporal metric at all, it is because we are trying to make sense of an inconsistent view.

But I do not think that it is part of the concept of geometrical structure that something's geometrical structure is intrinsic. In fact, several people have defended views according to which some kind of geometrical structure is extrinsic. One example is the view that material bodies inherit their geometrical properties (including their shapes) from the regions of space they occupy. On this view, the shapes of material bodies are extrinsic.[11] Another example is the platonist view that the fundamental spatial relation is *the distance between x and y is r*—a relation between points of space and numbers. This is a view according to which the geometry of space is extrinsic.[12] When I reflect on these views, they seem like coherent views that we should take seriously, not views that are analytically false.

So to ask what distinguishes the claim that the temporal metric is extrinsic from the claim that there is no metric at all is not to ask a question with a false presupposition. What, then, is the answer?

4 The Conventionalist Answer

The puzzles in the previous section are generated by the fact that many extrinsic relations on temporal intervals are formally eligible to be temporal metrics—they satisfy the relevant geometrical axioms—but nevertheless fail to be temporal metrics. So while satisfying those formal requirements is necessary, it is not sufficient, for being a temporal metric. What other conditions are required?

In this section I will discuss an answer to this question that I will call "the conventionalist answer." The claims that comprise the conventionalist answer resemble claims made by historical conventionalists like Poincaré and Grünbaum. But I am not sure they would recognize the way that I have articulated the puzzle that conventionalism is supposed to solve. In any regard, my interest is in the conventionalist answer's merits as an answer to my question, not its merits as an interpretation of those philosophers.

According to the conventionalist answer, *the earth rotates the same number of degrees during x as during y* gets to be the temporal metric because we have established linguistic conventions according to which it, and none of its competitors,

[11] I discuss this view in my [Skow 2007]; [McDaniel 2007] defends it.

[12] Field [1989] calls this view "heavy duty platonism." I don't know of many explicit defenses of this view, but I suspect that many philosophers believe it. Mundy [1983] defends a view of this kind (though on his view the fundamental spatial relation is not *the distance between x and y is r*, but is some other relation to numbers). In my [Skow 2007] I defend the claim that on this view geometry is extrinsic, but I do not defend the view itself.

is the semantic value of our expression "temporal interval x is the same length as temporal interval y." (These conventions may not be explicit; they may be implicit in the way we use our words.) But conventionalists do not think that we established such conventions because this relation was more intrinsically worthy than its competitors. Either our decision was arbitrary, or it was based on other criteria.

Here is my official statement of conventionalism about the temporal metric. It comprises two claims:

(1) Necessarily, all the extrinsic relations that are candidate meanings for "the same amount of time passes during x as during y" are equally qualified.

(2) Necessarily, there is an extrinsic temporal metric just in case (there is no intrinsic temporal metric and) our linguistic conventions select one of the candidate extrinsic relations as the semantic value of "the same amount of time passes during x as during y." The selected candidate is the temporal metric.

Some of the terms that appear in this statement need more explanation. First, "candidate meaning": by "candidate meaning" I just mean a relation that is formally eligible to be a temporal metric—it obeys the right geometrical axioms to be a congruence relation on times. Next, conventionalism says that the candidate meanings are "equally qualified" or "on a par." What do I mean by these terms? They are best explained by looking at an example in which (the analog of) the conventionalist answer is clearly correct. Think about planets. What is a planet? Once upon a time, the answer was obvious: the planets were the relatively large bodies orbiting the sun; and we identified nine of them. But then our telescopes got better and we got into trouble. We discovered bodies orbiting the sun that are larger than Pluto; but we balked at calling them "planets," even though "If something orbits the sun and is larger than some planet, then it is itself a planet" sounds analytic. Astronomers found this situation intolerable, so they got together to *legislate* a new meaning for "planet." (Or, if you like, to precisify "planet,"—maybe you don't think precisifying a word gives it a new meaning.) It took them a long time to do this and some of them got very angry. Why? Because, given the recent astronomical discoveries, there is no natural boundary dividing the set of bodies that orbit the earth into the larger bodies and the smaller bodies.[13] All the candidate meanings for "planet" are on a par.

If there were a natural boundary, the obvious thing for the astronomers to do would be to identify that boundary with the boundary between the planets and the non-planets. Without a natural boundary the astronomers had no guidance. Forced to give "planet" some new meaning, they "made up" a boundary of their own. The difference between planets and non-planets, on the new meaning of "planet," is for this reason merely conventional. Alien linguists learning our language for the first time might find themselves wondering what one of the smaller planets is doing that one of the larger asteroids isn't, that explained why only one of them is a planet. The conventionalist answer (applied to planets) would dissolve their puzzlement.

Conventionalists about the temporal metric think we are (or were at some point) in the same position as the astronomers. For practical reasons, we couldn't just leave the predicate "the same amount of time passes during *x* as during *y*" meaningless, or completely indeterminate in meaning. We needed to precisify it, but no one precisification was better than any other. So we made an arbitrary decision.

When I say that the decision was "arbitrary," I do not mean that (according to conventionalism) we had no reason at all to choose one meaning rather than another. Perhaps choosing one of the eligible relations rather than the others made for easier mathematical calculations when we did astronomy, or rocket science. Or perhaps choosing one of them made it easier to measure time. (Choosing the rotation of Pluto as our standard, for example, would make it very hard to measure the time.) As I will understand conventionalism, it contains the claim that pragmatic reasons like these are the *only* kinds of reasons we could have to choose one of the candidate meanings.

Before I turn to evaluating the conventionalist answer (applied to temporal metrics), I want to say a word about a famous complaint about conventionalist views. Putnam [1975a], following Eddington, claimed that conventionalism about

[13] Or, if there remains some natural boundary, we can imagine that things turned out even worse: suppose that we had discovered that there were bodies orbiting the sun of almost every size between the size of the earth and the size of some tiny asteroid.

the temporal metric is just a consequence of Trivial Semantic Conventionalism. Trivial Semantic Conventionalism is the view, roughly, that our words mean what they do because of the linguistic conventions we have established. Putnam claims that Trivial Semantic Conventionalism is obviously true and that everyone knows that it is. If conventionalism about the temporal metric follows from it, he argued, then it is also obviously true and philosophically uninteresting.

It should be clear that what I am calling "conventionalism about the temporal metric" does not follow from Trivial Semantic Conventionalism. Conventionalism about the temporal metric contains a claim about the nature of the candidate meanings for "temporal interval x is the same length as temporal interval y." It is the claim that all these meanings are on a par, that none stands out from the others (claim (1) above). The denial of this claim is compatible with Trivial Semantic Conventionalism. Even if the candidate meanings are not all on a par, we could still get "temporal interval x is the same length as temporal interval y" to mean any one of them by making the right sorts of stipulations. We could even get it to mean some relation that is not a candidate at all—a relation that is not a congruence relation on times. We could get it to mean what we actually mean by "x is at least three feet away from y," if the way we used the predicate departed radically from the way we actually use it. Since Trivial Semantic Conventionalism is compatible with the denial of conventionalism about the temporal metric, it does not entail it.

If the conventionalist answer is correct, then it helps explain why it is hard to see just what someone who thinks the temporal metric is extrinsic and what someone who denies there is a temporal metric at all are arguing about. When I look at their dispute, it looks like a dispute about the answer to a metaphysical question: whether time has a certain kind of structure. But if conventionalism is correct, then it is not. (Maybe some conventionalists did think that the geometrical structure of time was somehow something we had power over—that time's structure depended on what conventions we established. But this is no part of conventionalism as I am understanding it.) According to the conventionalist answer, the parties to this dispute agree about what the world is like. They have just established different linguistic conventions.

5 Robust Extrinsic Metrics

Conventionalism stands or falls with the truth of claim (1). (2) is only plausible if (1) is true; someone who accepts (2) but not (1) could fairly be accused of endorsing Trivial Semantic Conventionalism.

I think the conventionalist answer is wrong because I think (1) is false. It is not a necessary truth that all candidate meanings for "the same amount of time passes during *x* as during *y*" are on a par.

Why would anyone believe (1) in the first place? Perhaps for the following reason. It is obvious that obeying certain geometrical laws is necessary for being the temporal metric. But all of the candidate relations satisfy those laws; so this feature does not pick out one from the rest. There are, of course, other features that do discriminate between candidates. An alternative to conventionalism, a theory according to which (1) is false, will have to identify one (or more) of these features as a feature that is relevant to determining whether a candidate relation is the temporal metric. But it is hard to see how any of those features could be relevant. For example, *the earth rotates through the same number of degrees during x as during y* makes reference to a terrestrial planet while *Jupiter rotates through the same number of degrees during x as during y* makes reference to a gas giant. But this hardly makes the first relation more qualified to be the temporal metric than the second relation.

While I agree about this particular example, I deny that, in general, there are no features in addition to formal eligibility that are relevant to determining whether a candidate relation is the temporal metric. Consider the following historical example, which I will use as an analogy.

Descartes was a relationalist about motion. He thought that all motion is the relative motion of material bodies. But he did not think that all relative motions were on a par. One kind of relative motion was special. According to Descartes, something undergoes true, philosophical motion just in case it is separating from the bodies immediately contiguous to it, considered as at rest [Descartes 1991: part II]. And what made this state of relative motion special, what separated it from the others, is that it was this state of motion that the laws of motion (allegedly) governed. Descartes' principle of inertia says that a body at rest will remain at rest, and a body in motion will continue moving in a straight line at constant speed, unless acted on by an outside force (which for him meant: unless struck by another material body). So for Descartes something that is not currently separating from the bodies immediately contiguous to it, and is not being struck by some other material body, will continue not to separate from the bodies immediately contiguous to it. But his laws say nothing about the conditions under which a body's *other* relative motions will change.[14]

Just as the laws may distinguish one kind of relative motion from the others, the laws may distinguish one candidate meaning for "the same amount of time passes during interval *x* as during interval *y*" from the others. Suppose that there is no intrinsic temporal metric. It could turn out that *the earth rotates through the same number of degrees during x as during y* plays a role in the dynamical laws that no other candidate relation plays. Maybe it is something's speed relative to the earth's rotation that determines, in accordance with the laws, what it will do next.

This example suggests the following alternative to conventionalism (call it "the simple view"). In addition to formal eligibility, playing the "temporal metric role" in the laws is a feature relevant to determining which candidate is the temporal metric.[15] That is, whichever candidate (actually) plays that role is the temporal metric. If we discover that that there is no such role to be played in the laws, then we will have discovered that there is no temporal metric.

At this point the conventionalist will ask: why does playing the temporal metric role in the laws earn one of the candidate extrinsic relations the right to be the temporal metric? I will answer: because by playing that role it is doing the sort of thing that temporal metrics do.

Don't misunderstand the simple view. On this view, neither the laws nor the role that the temporal metric plays in the laws appears in the temporal metric's

[14]Of course, as Newton [2004a] argued, Descartes' laws do not really fit all that well with his definition of "true, philosophical motion." But that should not be a problem for the analogy I wish to draw.

[15]I will not given a precise definition of "the temporal metric role." Different versions of the simple view might define this term differently. None of my arguments turn on how this term is defined.

analysis. The analysis makes reference only to the earth's rotation. The fact that *the earth rotates through the same number of degrees during x as during y* plays the temporal metric role in the laws serves only to *justify* the claim that this analysis is correct.

If you believe that the temporal metric is extrinsic, and you adopt this simple view, you're going to face some tough questions about the modal consequences of your view. Suppose you claim that extrinsic relation *R* is the temporal metric. And to justify this claim you cite the fact that *R* plays the temporal metric role in the laws. Do you think that it is *necessary* that *R* plays that role in the laws? You might be in trouble either way. If you say "yes," some will say that your view places implausible restrictions on what the laws might be. If you say "no," then others will say that your view leads to skepticism. (They will say: what about those poor people in possible worlds at which some extrinsic relation other than *R* plays the temporal metric role in the laws? Those people will end up with false beliefs about which relation is the temporal metric. We're lucky we're not in one of those worlds. But if it is just a matter of luck that our belief that *R* is the temporal metric is true, then that belief is not justified.)

If you don't like either answer but you don't want to be a conventionalist, there are alternatives to the simple view. Here is one: do not identify the temporal metric with the first-order relation that plays the temporal metric role the laws. Instead, identify it with a second-order relation: *x and y instantiate the unique relation that plays the temporal metric role in the laws.*[16]

I don't think the simple view is in that much trouble, though. If I were to defend the simple view, I would deny that it is essential to the temporal metric that it play the temporal metric role in the laws. But I would also deny that this leads to skepticism. After all, *R* is the *temporal metric*. Possible worlds with strange

[16]If the temporal metric is some kind of second-order relation defined in terms of the laws, then it may be possible for the entire universe to evolve in time faster than it actually does. This is possible if there is a possible world in which the universe passes through all the instantaneous states that it actually does, but the laws are different, and these different laws select as special a first-order extrinsic relation other than the one the actual laws select. Whether there is such a possible world is open to dispute. (Humeans about laws (for example, [Lewis 1983]) will deny it.)

laws that do not relate in the usual way to the temporal metric are going to be very far away from the actual world. If far-off worlds where I'm a brain in a vat don't prevent me from knowing I have hands, these far-off worlds shouldn't prevent me from knowing that R is the temporal metric. But my goal in this paper is not to defend any particular alternative to conventionalism. I only claim that some alternative is viable. (I've only discussed alternatives to conventionalism according to which the feature *playing the temporal metric role in the laws* is the feature that makes the relation that has it into the temporal metric. But there may be defensible alternatives to conventionalism—analogues of either the simple view or the second-order alternative to the simple view—that pick some other feature.[17])

6 Two Objections

In my argument against conventionalism I gave an example that (I said) shows that some candidate extrinsic relation could stand out from the rest by playing a special role in the laws. Doubts might be raised, though, about whether the scenario in the example is really possible, and about whether it achieves its purpose.

Laws in which an extrinsic relation (like, for example, one that makes reference to my watch) plays the temporal metric role are strange. If laws like that are actual, then how something in the Andromeda galaxy—a long way away—behaves depends on how fast it is moving relative to my watch. Laws like that are non-local, for one thing, and they are non-qualitative, they "make reference" to a particular thing, for another. One might object to what I have said, claiming that such laws are impossible. In section 7 I will discuss this objection and dispute the claim that

[17] I do want to briefly mention one alternative, since it looks at first more appealing than the alternative I use in the body of the paper. Why not invoke the distinction between fundamental and non-fundamental properties, and say that (for example) *the earth rotates the same number of degrees during x as during y* is the temporal metric and *Venus rotates the same number of degrees during x as during y* is not because only the former is a fundamental relation? This will not work, because in fact neither relation is fundamental. (Since these relations are extrinsic, they have analyses; and any relation with an analysis is non-fundamental.) Nor will it work to say that the former relation is, at least, more fundamental than the latter. In so far as I can judge such things, these two relations look equally fundamental.

if an extrinsic relation plays the temporal metric role in the laws, then the laws must be non-qualitative.

There is another objection to my example I want to discuss first. One might claim that it is impossible for some laws to distinguish one candidate extrinsic relation from the others, and defend this claim like this:

> Suppose we have written down an accurate statement of the laws that refer to your watch in their definition of "velocity" and other relevant terms. This does not show that your watch plays a special role in the laws that mine does not. That is because we could also write down a statement of the laws that refer to my watch in these definitions. If we make appropriate changes elsewhere, the new law-statements will be notational variants of the old ones: they will express the same propositions in a different language. So it is not right that only one of our watches plays a special role in the laws. Once again, our watches are on a par. So you have not shown us a property that distinguishes only one of the candidate relations.[18]

Let's get clearer on how this objection works. The key claim being defended is

(3) It is impossible for one candidate extrinsic relation to play a special role in the laws.

The rationale we are offered for (3) is

(4) For any possible set of law-statements that makes reference to one physical process, there is another set of law-statements that makes reference to some other physical process, and which is a notational variant of the first set of law-statements.

So, on this objection, the scenario I described in the previous section merely *appears* to be one in which the earth plays a special role in the laws. Failure to recognize that (4) is true generates this illusion of possibility.

[18]This ploy may look familiar. It closely resembles arguments given by Poincaré [2001: part V], Grünbaum [1968: 59-70], and [Reichenbach 1957: 30-37].

Let's evaluate this objection. What reason is there to accept (4)? Time was you could argue for (4) by establishing that the two sets of law-statements are observationally equivalent, and then using the following premise: if the new law-statements and the old law-statements have all the same observational consequences, then the two sets of law-statements are notational variants.[19] If one is a verificationist then one will accept this premise; but I am no verificationist. And, verificationism aside, I don't think this premise has much going for it. Two sets of law-statements may agree on their observational consequences but differ in their theoretical apparatus. They may disagree, for example, on whether some material body is suffering a net force. In that case, they are not notational variants.

So far I've just wondered whether there is any good reason to believe (4). I will now turn to positive arguments against (4). I have two of them.

The first argument is short. The first set of law-statements in the indented passage entails that if anything moves, then my watch exists. The second does not; it entails that if anything moves, then *your* watch exists. Since the two sets of law-statements differ in their consequences, they are not notational variants.

This first argument, if it is sound, establishes that *every possible* set of law-statements that makes reference to my watch fails to be a notational variant of a set of law-statements that makes reference to your watch. But this is a stronger conclusion than I need. I only need to defend the claim that there is *some* possible set of law-statements that makes reference to my watch that fails to be a notational variant of a set of law-statements that makes reference to your watch. My second argument, which I turn to next, is a defense of this weaker claim.

My second argument requires some stage-setting. Let us look at one procedure one might apply to laws that mention my watch to produce new laws that mention your watch and are notational variants of the old laws. I assume that our watches do not run at the same rate; sometimes my watch run faster than yours and sometimes slower.[20] Let's assume that one of the old laws is a version of the

[19]This version of the argument is the standard interpretation of [Reichenbach 1957]; see [Putnam 1975b] and [Friedman 1983: 296].

[20]Normally when I say "My watch is fast" I mean only that it is set ahead of local time, not that each tick of its second hand is shorter than a second. But here when I say "my watch runs faster than yours" I do mean that each tick of my second hand

law of inertia: free bodies move in straight lines at a constant speed, relative to my watch. Now, if we use your watch as our standard for time, then free bodies will not move in straight lines at constant speed. Instead, they will move in straight lines but they will speed up and slow down. So we could write down new laws that refer to your watch and contain a complicated alternative to the law of inertia. The law will say how a free body's speed varies with time. (Depending on the pattern of disagreement between our watches, this new law may be incredibly complicated.)

I claim that, in this example, the new laws are not notational variants of the old laws. The two sets of laws are not true in all the same possible worlds. Here is the argument: it is compatible with the old laws that our watches run at the same rate. In a possible world in which they do, free bodies move at constant speed relative to both my watch and your watch. That means that the new laws are false in that world. So there is a world in which the old laws are true and the new laws are false. Since two sets of laws are notational variants only if they are true in all the same possible worlds, it follows that the old laws and the new laws are not notational variants.

Of course, I only looked at one procedure for trying to generate news laws that are notational variants of the old laws. What about other possible procedures? Could they succeed where this one fails? Any procedure will fall prey to the same kind of argument. For example, consider the following alternative procedure. Suppose that our watches are very old and each keeps a complete record of how much time has passed, according to it. So at the moment of Jesus's birth they both read (say) "0," and each has counted continuously the number of times its second hand has ticked since then in arabic numerals on its display. Since my watch runs faster than yours and sometimes slower, they do not now display the same number simultaneously. But there is some function f such that when your watch reads t my watch reads $f(t)$. Rewrite the laws to refer to your watch instead of mine using the following procedure: first, re-interpret the variable "t" to refer to the number dis-

is shorter than each tick of yours. ("My watch ticks faster than yours" makes sense even if there is no temporal metric. This is easiest to see if we suppose our watches have continuously moving second hands. Then my watch ticks faster than yours during some interval of time just in case my watch's second hand moves farther during that interval than yours.)

played on your watch; then replace all occurrences of it with "$f(t)$." These two sets of laws will then agree on how much time has elapsed between any two instants, and so will agree that free bodies move at constant speed.

This procedure fails to generate new laws that are notational variants of the old laws for the same reason as the first procedure. It is physically contingent that the numbers displayed on our watches are related by f. They could, instead, be related by identity. In a possible world in which they are, our watches run at the same rate. As before, the old laws are true at that world but the new laws are false.

That concludes my presentation of two arguments against the claim that it is impossible for the laws to distinguish one candidate extrinsic relation from the others. I now return to the objection I mentioned at the beginning of this section.

7 Qualitative Extrinsic Metrics

I claimed that the laws might distinguish one candidate meaning for "the same amount of time passes during x as during y" from the others. But I also noted a problem with this claim. All the candidates I've mentioned are extrinsic relations; but they are also non-qualitative relations. They make reference to a particular individual. (My favorite example makes reference to the earth.) But many philosophers claim that the laws of nature are purely qualitative.[21] If they are right, then for any relation R, if R plays the temporal metric role in the laws, then R is a qualitative relation. So: all my examples of extrinsic temporal metrics are non-qualitative relations. Perhaps it is *necessary* that an extrinsic temporal metric is not a qualitative relation. Then it follows that, necessarily, no extrinsic temporal metric plays the temporal metric role in the laws.

We have here an argument that apparently shows that it is impossible for the laws to distinguish one candidate relation from the others. If the argument is a good one, then I do not have an example that refutes conventionalism.

That my example extrinsic temporal metric figures in the laws has related absurd consequences. If it plays the temporal metric role in the laws, then it is

[21] The influence of this doctrine has waned as the influence of logical positivism has waned. So among others, Lange [2000: 34-9] and Lewis [1983] deny that the laws must be purely qualitative.

physically necessary that the earth exists. But that seems hard to believe.

I do not think these arguments work. I deny the premise that necessarily, an extrinsic temporal metric is not a qualitative relation. There can be qualitative extrinsic metrics. For example, suppose that for two temporal intervals to have the same length is for the center of mass of the universe to move the same distance during each of them. If this metric plays the temporal metric role in the laws, there is no particular thing such that it is physically necessary that it exists. The laws are purely qualitative.

This is merely an example. I don't mean to suggest that this is the only possible qualitative extrinsic metric; others are possible. Still, I want to explore a little bit what the world would be like, if that were the temporal metric.

First, what is the (intrinsic) spacetime geometry? Obviously, it has no intrinsic temporal metric. But it appears that the spacetime geometry must allow us to make sense of the distance between two non-simultaneous points of spacetime.

The reason is this. In order for the extrinsic temporal metric, as defined, to make sense, there must be facts about whether the center of mass of the universe has moved the same distance during two time intervals. For only then can we define two time intervals to be the same length just in case the center of mass of the universe has moved the same distance during each of them. One way for there to be facts of this sort is for our spacetime geometry to provide a notion of absolute space: for there to be facts about the spatial distance between any two points of spacetime, including non-simultaneous points.

Earman [1989: 27-36] provides a list of classical (non-relativistic) spacetime geometries, ordered from those with less structure to those with more structure. The spacetime geometry I have just described is not on the list. That is because no philosopher has taken it seriously as a possible spacetime geometry. Philosophers who deny that there is an intrinsic temporal metric are also hostile to absolute space. But it does not follow that that spacetime geometry is impossible. It does not lead me to think that there is something incoherent in the scenario I described.[22]

[22]Why not use Galilean spacetime in my example, and say that two intervals of time are the same length just in case the center of mass of the universe moves the same distance during each of them, in any inertial frame of reference?

Now for my second point. If the laws and the temporal metric are as I said, then there we have a kind of holism. How fast some material body is moving depends on how fast it is moving relative to the motion of the center of mass of the universe. But the way the center of mass of the universe moves depends on how each of the material bodies in the universe is moving. So even if some material body were located at just the places it actually is at each time, it might still have moved at a different speed, had some other (perhaps very distant) material bodies moved differently, or not existed at all.

Again, I don't think this fact suggests that there is anything incoherent in the scenario I described. I think it is just what we should expect from a world with an extrinsic temporal metric. And here I can claim that this is similar to other things some believers in extrinsic temporal metrics already accept. Consider the principle of inertia: a body unacted on by any force will not accelerate. Mach, for example, does not accept this principle as Newton understands it, because Newton understands "accelerate" as "accelerate relative to absolute space (and absolute time)." Mach proposes a replacement: a body unacted on by any force will not accelerate relative to the center of mass of the universe [Mach 1960: 286-8]. That is, its distance from the center of mass of the universe will change at a constant rate.[23] So Mach, who denied that there is an intrinsic temporal metric, is willing to refer to a body's changing distance from the center of mass of the universe in his statement of the laws. This leads to the same kind of holism I found in the possible world I described, in which a body's speed relative to the motion of the center of mass of the universe appears in the laws.

The example will not work with Galilean spacetime, because that spacetime comes with an intrinsic temporal metric.

[23]This replacement does away with reference to absolute space but not to absolute time. For this and other reasons, it is not adequate for Mach's purposes. (As Huggett [1999: 187] points out and as Mach was aware, something that orbited the center of mass of the universe at a constant speed would not be accelerating, according to this definition.)

8 Conclusion

I began this paper by exploring the distinction between intrinsic temporal metrics and extrinsic temporal metrics. I then discussed a puzzle: from a certain point of view it is hard to see how the claim that there is an extrinsic temporal metric differs from the claim that there is no temporal metric. What does an extrinsic relation have to do to become the relation that is responsible for time's geometrical structure? I argued that the conventionalist solution to the puzzle is wrong. I suggested, instead, that an extrinsic relation can get to be responsible for time's geometrical structure by playing some special role in the laws of nature.[24]

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